

**SYSTEM AND METHOD FOR
PACKET DATA SERVICING NODE (PDSN)
INITIAL ASSIGNMENT AND RESELECTION**

5 **Background of the Invention**

 This invention generally concerns wireless communications
and, more particularly, a system and method for assigning a Packet Data
Serving Node (PDSN) to a wireless mobile station (MS), to provide packet
data services in a third-generation (3G) code division multiple access
10 (CDMA) communication system.

 In the second generation CDMA systems specified by the IS-
95B standard, uplink data bursts from a MS to base station are limited to
a small number of frames, typically 8 or less. The data rate is limited to
4.8 kbps, i.e., inferior to the one used by the users active on the dedicated
15 (voice) channels, which is 9.6 or 14.4 kilobits per second (kbps). The 3G
CDMA, as described in IS-2000 body of standards, is being designed to
accommodate both longer messages (more frames per message) and higher
data rates to support the communication packetized data. Data rates of
384 kbps are envisioned. The ability of the 3G CDMA to communicate
20 packet data will permit users to seamlessly access the Internet with a
computer through a wireless telephone.

 The transfer of large volumes of data between the MS and
the PDSN portal to the Internet will be aided by changing the 3G CDMA
system from the traditional PSTN circuit-switched system, where the data
25 network communication must be routed through the mobile switching
center (MSC), to a system where the PDSN can locally connect to a radio

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access network (RAN) base station controller (BSC) using frame relay, or
some other link-layer transport capable of carrying Internet protocol (IP)
data packets. The linkage between the wireless system and the Internet
can be more peer-to-peer and, therefore, simpler and faster, if the packet
5 data protocol can be maintained across the PDSN.

Fig. 1 illustrates the architecture for the 3G CDMA radio
access network (RAN), prior art. The packet control function (PCF) and
PDSN are two new entities defined by the third-generation Partnership
Project 2 (3GPP2) and are only relevant to packet data calls. The
10 cardinality of PDSN and PCF association is many-to-many, meaning that
it will be typical for many PCFs to be connected to each PDSN. Likewise,
it will be typical for many PDSNs to be connected to each PCF.

When a packet data call is first established, by an MS
request for example, a BS and associated BSC are selected as elements in
15 the link. Typically, the BSC is associated with a particular PCF, which
may even be co-located at the BS. The PCF must be connected to a PDSN,
or a PDSN must be (initially) selected for the MS. There is currently no
IS-2000 standard for the initial PDSN assignment.

Furthermore, the packet data link between the MS and
20 PDSN, once initially selected, may become dormant as the MS ceases to
communicate packet data. In this situation the air interface traffic and
control channels are released, but the point-to-point (PPP) connection
between the PDSN and the MS are maintained. It is foreseeable that a
dormant MS will roam. Regardless of the relationship between PCFs and
25 BCSs, a dormant MS will roam to a different packet zone (i.e. a new PCF).
The new PCF must be notified and it must then establish a new

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In one aspect of the invention, the wireless communication system includes a plurality of m PCFs and a plurality of n PDSNs with unique IP addresses. Then, the method comprising: at each PCF, generating a record of PDSN Id numbers; and selecting the PDSN Id number in response to the total number (n) of PDSN Id numbers in the record, and in response to the MS IMSI.

Not all the PDSNs listed in the selection table need be connected to the first PCF hosting the table. When the first PCF is not connected to the IP address associated with the first PDSN Id number, the connection cannot be made. Then, the method further comprises reselecting an alternate PDSN Id number, after the first PDSN Id number has been calculated. In one aspect of the invention, the reselection of an alternate PDSN Id number includes varying the first PDSN Id number, typically by adding "1", and dividing that varied number by n . Then, the PDSN with the number equal to the remainder in the quotient is selected.

Alternately, the reselection of an alternate PDSN Id number includes: removing the first PDSN Id number and associated IP address from the table; dividing the MS IMSI by the number of PDSNs remaining in the table; and selecting the PDSN Id number equal to the remainder in the quotient.

A wireless communication system for communicating packet data is also provided. The system comprises a first mobile station (MS) having a unique identification number (Id), such as its IMSI, and a transceiver for wireless packet data communications. The system comprises a plurality of m PCFs. Each PCF has a port for packet data communications with MSs, and with at least one of a plurality of n PDSNs. Each PDSN has a port for packet data communications, a unique IP address, and a unique (identification) number. Each PCF includes a table with an ordered sequence of the n PDSN Id numbers cross-referenced with the n IP addresses. Because of the common ordering of PDSN Id numbers in the tables, each PCF selects the same PDSN Id number for packet data communications involving the first MS. The selection process is responsive to the first MS Id, and the number of PDSNs in the table.

Brief Description of the Drawings

Fig. 1 illustrates the architecture for the 3G CDMA Radio Access Network (RAN), prior art.

Fig. 2 depicts an exemplary connection of PCF units and PDSN units in a wireless communication system.

Figs. 3 and 4 depict exemplary partially-connected network of PCF and PDSN units.

Fig. 5 depicts the addition of a PDSN unit to a network of PCF clusters.

5 Fig. 6 is a flowchart illustrating the present invention method for selecting a PDSN for packet data communications with a first MS.

Fig. 7 is a flowchart illustrating an alternate depiction of the present invention method for selecting a PDSN for packet data
10 communications with a first MS.

Detailed Description of the Preferred Embodiment

In short, the heart of the invention is a methodology embodied in a set of machine executable instructions. Typically, the
15 instructions are written in a medium which can be accessed as memory by a computer, or which can be read by a computer. The set of instructions are typically embodied as a computer application which orders the computer microprocessor to perform the series of steps needed to cause a PCF to select a PDSN in accordance with the algorithm described in detail
20 below.

A PDSN table must be configured at PCF. Each PCF maintains a table that includes all PDSNs it is connected to. Each table entry must contain (but is not limited to) a PDSN identification (Id) number, and an IP Address associated with the PDSN. It is important
25 that the PDSN Id numbers are assigned consistently, stored in a predetermined ordered sequence (ascending or descending) in all PCFs.

An example of such a table, such as might be configured in a PCF is shown below (Table 1).

TABLE 1

5		PDSN Number	IP Address
		0	aaaa
		1	bbbb
		...	
10		$n - 1$	xxxx

The PDSNs are (locally) numbered from 0 to $(n - 1)$ and are stored in ascending order based on PDSN IP addresses. It is assumed that $aaaa < bbbb < \dots < xxxx$, and that n is the total number of PDSNs available to this PCF. As explained in more detail below, a PDSN can be entered into a selection table, even if that PDSN is not connected to the PCF hosting the table.

The PCF determines which PDSN to select for a particular
 20 MS based on the unique identification number (Id) of the MS. Typically,
 the IMSI is used. Then, the following calculation is performed:

$$\text{PDSN No.} = (\text{Mobile IMSI}) \bmod n$$

25 It is understood that modulo n is a computational process where the remainder of a quotient is used as the answer. In this case the quotient is the MS IMSI divided by n . Note that n is the total number of locally available PDSNs to this PCF, not that of the entire network.

Fig. 2 depicts an exemplary connection of PCF units and PDSN units in a wireless communication system 10. There are n PDSN units with the PDSN Id Nos. of "0" (12), "1" (14), and "2" (16), where n is equal to three. The respective IP addresses of PDSN units 12-16 are "001", "002", and "003", shown in Table 2 corresponding to an ordered sequence of PDSN Id numbers. Also shown in Fig. 2 are m PCF units, PCF 1 (18), PCF 2 (20), and PCF 3 (22), where m is equal to three. The PCF units 10-22 are all configured with a PDSN initial selection table. Table 2 is the PDSN selection table for PCF 1 (18). Both the PCF and PDSN units have ports for the communication of packet data. A first MS 24 is shown having a transceiver for the communication of packet data. The first MS 24 is connected to the first PCF 18 through other elements in the system 10, not shown. PCF 1 (18) is shown assigned to interface the first MS 24 with a PDSN.

	PDSN Number	IP Address
20	0	001
	1	002
	2	003

If the selected PDSN is not available, for reasons such as lost of connection, exceeding PDSN capacity, or simply no existing physical

In one aspect of the invention, the continuous selection

$$\text{PDSN No.} = (\text{last selected PDSN No.} + 1) \text{ modulo } n$$

10 IMSI is 3,000,001:

$$\text{PDSN No.} = (1 + 1) \text{ modulo } 3 = 2$$

20 In another aspect of the invention the reselection process is handled differently. The number n is reduced by one, and the calculation repeated as follows:

$$\text{PDSN No.} = (\text{Mobile IMSI}) \bmod (n - 1)$$

However, this process does not always work. In terms of the
 25 example given above where $n = 3$ and the IMSI is 3,000,001:

PDSN No. = (3,000,001) modulo 2 = 1,

which is the same result received in the initial selection
where PDSN 1 (14) was selected. That is, the reselection process failed to
5 select a new PDSN. However, this concept can be made to work with
modifications. One modification involves temporarily removing the last
selected PDSN Id No. from the table, and renumbering the table.

For example, assuming that the initial selection process
selects PDSN 1 (14) (i.e. PDSN No. = IMSI % 3 = 1), but PDSN 1 (14) is
10 not available. Then, the PDSN table is temporarily changed, for this
mobile 24 only, to Table 3. Alternately stated, Table 3 is the PDSN
selection table of PCF 1 (18), modified for the reselection process, when
the initially selected PDSN is not available.

15 Table 3

PDSN No.	IP Address
0	001
1	003

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The old PDSN 1 (14) is temporarily removed from the table,
and the old PDSN 2 (16) now becomes PDSN 1, as a result of keeping the
PDSN Id numbers in an ordered sequence, or ascending re-ordering. The
continuous selection uses the updated table to select between PDSN of
25 address "001" and "003" using IMSI % (modulo) 2 in this example. After a
successful continuous selection, the original PDSN table (with three
entries in this example, Table 2) is restored for next normal Selection as
described above.

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first MS 24. In a system that is not fully connected the same result is guaranteed if the selected PDSN happens to be connected to every PCF. Assuming that the first MS IMSI is still 3,000,001, and n is equal to 4, the first PCF 18 selects PDSN 1 (14) as follows:

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$$\text{PDSN Id No.} = (3,000,001) \text{ modulo } 4 = 1$$

If the first MS 24 is later assigned to the second PCF 20, the selection process selects the same PDSN Id number, because the PCFs use the same sequence in their tables. Because the first PCF 18 and the second PCF 20 are both connected to PDSN 1 (14) the IP address is maintained without the requirement of a new PPP being established.

Table 5, below, depicts the PDSN selection tables configured in PCF 1 (18) and PCF 2 (20) of Fig. 4.

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Table 5

Before Adjustment: (assume IP address a<b<c<d and ascending ordering used)			
@PCF1:		@PCF2:	
PDSN No.	IP Address	PDSN No.	IP Address
0	001	0	003
1	002	1	004
2	003		
After Adjustment			
@PCF1:		@PCF2:	
PDSN No.	IP Address	PDSN No.	IP Address
0	001	0	"dummy" address flag no connection
1	002	1	"dummy" address flag no connection
2	003	2	003
3	"dummy" address flag no connection	3	004

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The invention advantageously ensures that the first mobile's PPP connection is maintained for the duration of a packet call as best as possible. The likelihood of selecting the same PDSN when a MS roams to a new PCF is a function of the actual PCF-PDSN connectivity at the new and old PCF. Although the selection process does not guarantee consistent PDSN selections if the network is deployed such that PDSNs and PCFs are not fully connected, the probability of selecting the same PDSN increases as the connectivity increases. In the degenerate case (full connectivity), this selection algorithm always selects the same PDSN for a given MS Id, because every PCF has the same PDSN table and uses the same n (the "global" n) for modulo operation.

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software required to support enhancements and changes to future all-IP architecture is easily modified, so the PDSN selection is forward compatible.

Fig. 5 depicts the addition of a PDSN unit to a network of PCF clusters. The selection method also addresses scalability, because the n used for modulo operation is the number of PDSNs locally available to the PCF. When removing a PDSN and the associated physical link, "dummy" entries can be used to replace the removed PDSN so that other entries in a PDSN table are not changed. PDSN selections will therefore not be disturbed. When adding a PDSN, only the (local) PCFs that need to add or remove a PCF-PDSN physical link need to be updated, not the entire network. Therefore, only the locally affected PCFs may suffer from re-selecting a different PDSN in this case (and if MS roams).

Expanding cluster 2, where a new PDSN (PDSN 4) is being added, will not affect cluster 1. Only those PCFs that will add a direct link with the new PDSN are effected, such as PCF 2. Therefore, all MSs that roam within cluster 1 will not be affected.

Fig. 6 is a flowchart illustrating the present invention method for selecting a PDSN for packet data communications with a first MS. Step 100 includes a wireless communication system with at least one Packet Control Function (PCF) and at least one Packet Data Servicing Node (PDSN). Although the method describes a sequence of numbered steps for clarity, no order should be inferred from the numbering unless explicitly stated. Step 102 generates a record of unique PDSN Id numbers. Step 104 assigns a unique MS identification number (Id) to the first MS. Step 106 is a product where a PDSN is selected in response to

In some aspects of the invention the system in Step 100 includes n PDSNs, with each PDSN in the system having a unique Internet protocol (IP) address. Then, the generation of the record of PDSN addresses in Step 102 includes creating a table with an ordered sequence of the PDSN Id numbers cross-referenced to the IP addresses. The selection of the PDSN in Step 106 includes dividing the first MS Id by the number of (n) PDSNs. More specifically, the selection of the PDSN in Step 106 includes selecting the PDSN Id number equal to the remainder in the quotient, when the first MS Id divided by n .

In some aspects of the invention the method further comprises Step 101, where the first MS communicates with a first PCF to request packet data communications. The generation of the table of PDSN addresses in Step 102 includes the first PCF having a table of cross-referenced PDSN Id numbers and IP addresses. The selection of the PDSN Id number in Step 106 includes using the table of the first PCF to calculate the PDSN Id number.

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identification number (Id) to the first MS. Typically, the IMSI number is used. Step 206 is a product where a first PDSN Id number is selected in response to the total number (n) of PDSN Id numbers in the record. The selection of the first PDSN Id number in Step 206 also includes selecting
5 the first PDSN Id number in response to the first MS Id.

In some aspects of the invention Step 201 assigns a first PCF, to establish packet data communications between the first MS and a PDSN. Then, the selection of the first PDSN Id number in Step 206 includes the first PDSN Id number being selected, regardless of which
10 PCF is assigned. Step 208 routes packet data communications between the first MS and the IP address corresponding to the selected PDSN Id number, through the assigned PCF.

The generation of the record of PDSN Id numbers in Step 202 includes creating a table with an ordered sequence of the PDSN Id numbers cross-referenced to the IP addresses. Then, the selection of the first PDSN Id number in Step 206 includes dividing the first MS Id by the number of (n) PDSNs in the table. Further, the selection of the first PDSN Id number in Step 206 includes selecting the PDSN Id number equal to the remainder in the quotient, when the first MS Id divided by n .
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In some aspects of the invention, the system of PDSNs and PCFs are not fully connected, which complicates the PDSN selection process. That is, Step 200 includes the first PCF being connected to a IP address corresponding to the second PDSN Id number, but not to the IP address corresponding the first PDSN identification number. Then, Step
20 207 reselects an alternate PDSN Id number, after the first PDSN Id number has been calculated.
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